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BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

# OIL CONTROL EXPERIMENTS DIRECTED AGAINST D. BREVICOMIS, D. MONTICOLAE AND FLATHEADS. SEASON of 1934

By

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and
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Bureau of Entomology and Plant Quarantine

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# OIL CONTROL EXPERIMENTS DIRECTED AGAINST

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## INTRODUCTION

Control of pine beetle broods by the application of toxic penetrable oils was first tried in 1932 with considerable promise of success, by a cooperative arrangement between the Bureau of Entomology and Standard Oil Research Laboratory. Continued experiments were carried on jointly by the two organizations during the fall of 1932 and throughout the summer of 1933. Results were so promising that three small experimental control projects were undertaken on the Sierra and Stanislaus National Forests during the Fall of 1933 by CCC and NIRA crews.

One oil, formula 21046/R, stood out in effectiveness over all others tried, but, in addition, another, 22436/R, was used in the experimental projects and proved to be ineffective. The results of the experimental control projects were not as gratifying as had been supposed, since it was found that the mortality of broods was greatly reduced compared with the success of summer projects. This led to the belief that temperature played an important role in effectiveness. Experiments carried out to this end during the early part of 1934 revealed that temperatures below 60 degrees were not conducive to high mortality, and that an effective kill was not reached unless the temperature reached 70° F or higher.

In the final analysis of mortality data in all experiments carried out during 1933, great variations and inconsistencies in results occurred, where identical conditions of application were evident. These variations were apparently due to differences in bark thickness and especially texture.

At the beginning of the 1934 summer season, it became obvious that if the oils were to be used successfully, certain factors would have to be eliminated. Thus the following main objectives were considered.

1. The development of an oil which could be used effectively at low temperatures.

2. A comparison in efficiency of new and old oil formulae.

3. The isolation of factors governing the penetration and effectiveness of oils.

4. The improvement in methods of oil application and technic.

Practical consideration of the oil control method, such as costs and transportation to infested area, were considered but are omitted intentionally in this report, since they will be discussed later in a general report of the entire field of oil control. All materials used are within reasonable limits when compared with other control methods.

Cooperation between the Bureau of Entomology and the Standard Oil Company was continued throughout these tests. New materials were developed and supplied by the Standard Oil Company. In addition several formulae were made up in the field, the ingredients of which were mixed by Bureau personnel.

The experiments included in this report were carried on in the vicinity of Bass Lake on the Sierra National Forest at elevations between 3,000 and 7,000 feet, where an abundance of D. brevicomis and flatheads in ponderosa pine, and D8 monticolae in sugar pine and lodgepole pine was supplied.

## MATERIALS AND METHODS

### Oil Formulae.

1. Formulae developed by the Standard Oil Company. With the exception of the first two, all the formulae listed were developed for use in 1934 experiments, with special attention to their application at low temperatures. The base oils and amounts of toxic substances added to each of these formulae is withheld as a policy of the Standard Oil Company, since none has been patented. The formulae are listed as follows:

| | |
|---|---|
| 21048/R | 23905/R |
| 22458/R | 23906/R |
| 23903/R | 23935/R |
| 23904/R | 23936/R |

2. Reilly stainless creosote. This material has been used with promising results in experiments carried on in the South and was recommended for trial against D. brevicomis by Dr. Craighead.

3. Other materials used to develop new formulae. The following 26 combinations were developed in the field and tried out during the course of these experiments.

   3a. Automobile crankcase drainings.

   3b. Heavy stove oil.

   3c. Crankcase drainings 50%, heavy stove oil 50%.

3d. Crankcase drainings 25%, heavy stove oil 75%

3e. Heavy Stove Oil and paradichlorobenzine 45 gms. per quart.

3f. " " " " beta naphthol 20 gms. per quart.

3g. " " " 50%, kerosene 50%

3h. " " " 80% " 20%

3i. " " " " " " , and paradichlorobenzine 10 grams per quart.

3j. Crankcase drainings 60%, heavy stove oil 30% and kerosene 10%.

3k. Heavy stove oil 50%, light stove oil 50%.

3l. " " " 50% " " " 50%, and PDB 45 gms. per qt.

3m. Light stove oil.

3n. " " " and PDB 90 gms. per quart.

3o. " " " 50%, crankcase drainings 50%.

3p. " " " 75%, " " 25%.

3q. Light stove oil 50%, heavy stove oil 50% and naphthalene one-half pound per gallon.

3r. Light stove oil 75%, heavy stove oil 25% and naphthalene one-half pound per gallon.

3s. Light stove oil 25%, heavy stove oil 75%, and PDB 45 gms. per qt.

3t. Light stove oil 90%, crankcase drainings 10%.

3u. Coal tar.

3v. Coal tar 50%, light stove oil 50%.

3w. " " 33-1/3%, light stove oil 66-2/3%.

3x. Wood tar.

3y. " " 50%, light stove oil 50%. (heavy fraction).

3z. " " 50% " " " " . (light " ).

Character of treated samples.

Samples treated throughout these experiments were sections, slabs, logs, and definite bark areas of beetle infested trees from ponderosa, sugar, and lodgepole pines. Bark thickness varied from one-quarter to one and one-half inches in the case of ponderosa pine, and from one-half inch to four inches in the case of sugar pines. A great deal of variation with respect to oil penetration was manifested by the various samples. An attempt was made in all cases to obtain samples for experimental work which contained heavy broods of one-half to three-quarter grown larvae, although it was not always possible.

Technic of oil application.

Oils were applied to measured bark surfaces of logs, slabs, and desired sections of an infested bole by means of a 4-gallon capacity Smith-Hanner sprayer, as evenly and thoroughly as possible, with special care to wet crevices, woodpecker holes and all openings and depressions in the bark. In a few cases where small samples were treated, the oils were applied with a paint brush.

Quantity of Oil Used.

As a rule, all oils were applied at the rate of one quart per ten square feet of bark surface. Variations of this dosage were sometimes used, however, where it was found desirable to experiment with different amounts of oil. In later experiments less attention was given to the amount of oil applied per unit of area and emphasis was placed on completely covering the bark and filling all crevices and depressions regardless of the actual amount of oil used.

Period of Exposure to Oils.

For the most part, especially at summer temperatures, the broods in treated logs were exposed to the oils for a period of two weeks, i. e., from the time oil was first applied to the bark until mortality was determined. In other cases during the summer, as short a time as one week and as long a time as three weeks exposure was allowed to take place. In the case of winter oil tests, exposures for as long as five weeks were allowed.

Mortality Analysis.

Counts of living and dead broods were made from treated bark samples after designated periods following treatment had passed. These periods were kept as near the same length as possible in different tests for comparative results, but often deviations were necessary because of lack of personnel at a time when mortality counts should be made. For this reason certain weaknesses are evident in the data presented.

Bark samples from treated ponderosa pine were analyzed by shaving up the entire bark to expose the D. brevicomis broods, while the D. monticolae broods in lodge pole and sugar pine found only along the cambium layer, were counted simply by separating the bark from the wood. As a rule samples of 1 square foot or less of bark were sufficient to determine the mortality of D. brevicomis in ponderosa pine, while samples of no less than 2 square feet of bark were used in determining the mortality of D. monticolae in lodgepole and sugar pines. A further check of the mortality of D. brevicomis broods was determined in some cases by allowing brood in the remaining bark area of treated samples to develop to maturity and emerge, after which counts on exit holes were made.

## COMPARATIVE TOXICITY OF OIL FORMULAE IN RELATION TO TEMPERATURE

### Experiment 1-A.

Object.- To determine the effectiveness of a number of new formulae developed by the Standard Oil Co. and stainless creosote at low (winter) temperatures on western pine beetle in ponderosa pine, mountain pine beetle in sugar and lodgepole pines and buprestid larvae in ponderosa pine.

Equipment, materials and procedure.-

1. These tests were carried out on ponderosa pine and sugar pine logs and lodgepole pine slabs at an elevation of 7200 feet between April 17 and June 8, 1934.
2. Oils 23905/R and 23906/R were used in one test covering 5 weeks, and oils 23905/R, 23906/R, 23935/R, 23936/R, and stainless creosote were used in another test covering 19 days. All were compared with untreated checks.
3. The bark thickness of all samples containing a given species was uniform, and thus eliminated as a variable in comparing mortality results.
4. Brood stages ranged from 1/2 to fully grown larvae on the average, with some younger and older stages found.
5. Thermograph records of air temperature were kept during the period of experiments, along with checks of bark temperature made at intervals by means of mercurial laboratory thermometers.
6. The exposure period of broods to the oils varied from six to thirty four days.

Results.- Graphic and tabular representation of results are presented in Figures 1, 2, 3 and 4 and Table I in the appendix. Maximum and minimum temperature summations taken during the period of this experiment are presented in Fig. 5. The following significant points were found:

1. In a five weeks' comparison in effectiveness of oils 23905/R and 23906/R on D. brevicomis broods in ponderosa pine and D. monticolae broods in sugar pine, the mortality of broods in each case was highest at the end of the period, with a gradual increase each week over the week previous.

2. Oils 23905/R and 23906/R caused higher mortality to D. brevicomis broods than to D. monticolae broods after 5 weeks' exposure; the highest mortality to D. monticolae was 86 per cent, while 100 per cent of the D. brevicomis brood was dead.
3. Oil 23906/R caused slightly greater mortality of both D. monticolae and D. brevicomis.
4. Neither of the two formulae 23905/R and 23906/R were as effective against Melanophila broods after an exposure of 4 weeks, as against barkbeetle broods. Formula 23906/R caused 80 percent mortality after 4 weeks.
5. Comparison between oils 23905/R, 23906/R, 23935/R, 23936/R and Reilly stainless creosote on lodgepole D. monticolae broods for a period of 12 and 19 days resulted in the highest kill for creosote at the end of 12 days, and the highest kill for oil 23936/R at the end of 19 days.
6. The same 5 formulae compared on ponderosa pine showed best results from formula 23936/R; all the other formulae were from 80 to 96% effective at the end of 19 days.
7. The temperature during this experiment never went above 80°F maximum or below 27 degrees minimum, the average temperature remaining between 40 and 50 degrees F.

Experiment 1-B.

Object.- To compare the effect of a large number of oils on western pine beetle in ponderosa pine, mountain pine beetle in sugar and lodgepole pines and buprestid larvae in ponderosa pine at average summer temperature.

Equipment and materials.-
1. All tests were made on brood logs and slabs of ponderosa pine, sugar pine and lodgepole pine.
2. Bark thickness varied from one half to one inch in ponderosa pine and from one-quarter to three-eighths inch in lodgepole pine. The sugar pine bark averaged one-half inch in thickness. The broods were in the larval stage for the most part. Logs varied from six to ten square feet in area and slabs averaged about one and one-half square feet in area.
3. Thermograph records of air temperature were kept at the location of these experiments during the time they were being conducted.

Procedure.-
1. The location of the set up for this work was an area on a sidehill adjacent to the Bass Lake station.
2. Oil was applied at the rate of .025 gallons per square foot, with two exceptions. In applying oil, the bark surface was covered and wet as thoroughly and completely as possible.
3. Logs and slabs after being treated were left in a shaded place where they would at no time be exposed to direct rays of the sun. This did away with any possibility of error in brood mortality counts due to sun-curing.

4. The period of exposure of the brood to the oils was varied from seven to twenty days in case of ponderosa pine infested by western pine beetle and sugar and lodgepole pines infested with mountain pine beetle. Ponderosa pine infested with buprestid larvae was checked at six and forty-one days after treatment.

5. The amount of bark area checked in making brood mortality counts varied with the bark and brood under consideration. In checking ponderosa, sugar and lodgepole for pine beetles, with very little exception the brood in one square foot of bark area was counted. When checking flathead brood in ponderosa pine, however, it was necessary to check several square feet of bark area each time counts were made.

Results.-

1. Figures 6, 7, 8, and 9 and Table 2 in the appendix present the results of these experiments. Summation of maximum and minimum temperatures are plotted on figure 10.
2. In general, Standard Oil formulae were more effective than most of those developed in the field against D. brevicomis broods. None of the new materials was tried on other insects.
3. Of the Standard Oil formulae Nos. 23903/R, 23904/R, 23905/R, 23906/R, 23935/R, and 23936/R gave consistent and effective results on Melanophila, D. brevicomis and D. monticolae broods, with variations in kill running higher in certain tests than in others, using the same species of insect for a given period.
4. Stainless creosote caused uniform and high mortality of broods.
5. Light and heavy stove oils combined with naphthalene in some tests and with paradichlorobenzine in others caused efficient and consistent brood mortality after a period of 7 days' exposure. A combination of heavy stove oil and paradichlorobenzine added at a rate of 45 gms. per quart caused 92.1% mortality of D. brevicomis broods.
6. Wide variation in mortality in bark of the same thickness was found when a given oil was applied in equal quantity per unit of bark area.
7. Ponderosa pine logs treated equally on all bark surfaces and left for mortality analyses, showed highest mortality on top and sides and lowest on the bottom. Mortality of broods on the bottom often were lowest when the most effective oils were used.
8. At summer temperatures maximum mortality of D. brevicomis and D. monticolae broods treated by oils is reached much sooner than of flathead broods; from 7 to 21 days was found sufficient to secure desired information on D. brevicomis and D. monticolae while 5 to 7 weeks is necessary before mortality of Melanophila broods can be obtained.
9. During the period of summer oil experiments, the average temperature remained around 70° F, while maximum temperatures were about 85 degrees F and minimum temperatures aroud 50° F.
10. Dosages over .025 gallons per square foot caused no appreciable increase in mortality of broods, while a less amount resulted in lower mortality.

## RELATION OF OIL PENETRATION AND TOXICITY TO PHYSICAL BARK CHARACTERS

**Experiment 2-A.**

Object.- To determine the relation between bark thickness and mortality of broods.

Materials.-

1. These tests were run on logs of ponderosa pine infested with western pine beetle in the first and second generations of the season.
2. The oils used in this work were formulae 21046/A and 23936/A.

Procedure.-

1. The infested trees from which the logs were cut were well spread out over the working area at the Bass Lake station. Logs were hauled to an experimental plot adjacent to the station in some cases, and in other cases were treated on the location of the infested tree. As in all the experimental work, the logs were shaded from the sun throughout the course of the experiments.

2. Bark thickness of the various logs treated in these tests ranged from one-quarter inch to one and one-quarter inch. Logs were cut from the infested trees at every quarter inch variation in bark thickness, as far as brood development made this possible. Thus the number of logs per tree varied from one to five. In the case of several logs being taken from one tree, the attempt was made to obtain a check log of medium bark thickness and not one from either extreme.
3. Oil was applied, as in all experiments, as evenly and with as complete coverage as possible, the log being rolled at the same time. The oil was applied to all logs at the rate of one quart per ten square feet of bark surface.
4. Brood mortality checks were made at one and two weeks after application of the oil.

Results.-

1. Correlation between bark thickness and mortality of broods in 50 logs from 13 different trees was evident in less than 50% of the cases. Figure II presents graphically the mortality in percent of D. brevicomis broods from 20 logs taken from 4 representative trees used in this experiment.
2. Variations and inconsistencies in results from different trees and from different logs of the same trees are due in part to bark texture differences, which may influence the penetration of oil, and to evident resistance of beetle broods to the oils.
3. Correlation between mortality and bark thickness in certain trees is evidently due to evenness in texture.

Experiment 2-B.

Object:- To determine the relation between the rate of oil penetration in the bark and the mortality of broods.

Materials.- The materials used for this work were bark samples from the same logs, as were used in experiment 'A' above.

Procedure.-

1. Bark samples of about one-half square foot in area were collected from each experimental log at the time of cutting and were then taken to the laboratory.
2. In the laboratory strips one-quarter inch thick and as wide as the bark thickness were cut out of the bark. The length of these strips was variable with the size of bark plates and heaviness of the bark for strips could be cut only from solid bark. The strips were suspended in small vials of jars containing a small amount of the oil which had been used in treating the original log. The lower end of the strip was allowed to just touch the oil and the length of time required for the oil to completely cover the strip was recorded. (See Photo 1.) Readings were taken at five, fifteen, thirty and sixty minutes for the first hour and every two, four, eight hours and so on thereafter. This was done only in the determination of longitudinal penetration, for in measuring the rate of vertical penetration it was necessary to make but one reading.

3. In determining the rate of penetration longitudinally, the distance traversed along the strips in two hours was used as a basis of computation as it took but two hours for complete coverage of the shortest strip on which the determination was made. The distance covered by the oil along the bark strips in centimeters during two hours time was divided by seventy-two hundred, giving the rate of penetration in centimeters per second.

3a. To determine vertical penetration, strips one-quarter inch thick and as wide as the original bark thickness were cut. The time for the oil to cover these strips was noted and the length of the strips in centimeters divided by the number of seconds required for coverage gave the rate of penetration in centimeters per second.

Results.-

1. Tables 3 and 4 present representative data obtained from this experiment, in which bark samples from 25 different trees were used.
2. No correlation was found between mortality of broods and rate of longitudinal penetration of oils in the bark.

3. Correlation between brood mortality and rate of vertical penetration, i. e., penetration through the bark, was evident in less than 50% of the cases.
4. Rate of oil penetration through the bark is evidently not an important factor causing brood mortality.

Experiment 2-C.

Object:- To determine the relation between bark density and mortality of broods in bark treated by toxic oils.

Materials.- Same logs and trees as experiment 'A'. Oils 23936/R and 21046/R were applied at a rate of .025 gallons per square foot of bark area.

Procedure.-
1. Blocks of untreated bark one inch square, coated by a very thin film of paraffin to prevent absorption of water, were weighed in green.
2. These were submersed in water and the number of cc. of water displaced was measured.
3. Determinations of density were calculated by dividing the weight of the block by the volume of water displaced.

Results.-
1. Representative data in this experiment are presented in Table 5.
2. Tests carried out on 60 samples of bark taken adjacent to treated blocks showed correlation in very few cases.
3. The general trend of results indicated that the higher the density the greater the kill, but so many exceptions are prevalent that the conclusion that no correlation exists is most probable.

## RELATION OF OIL PENETRATION AND TOXICITY TO MODIFICATIONS IN APPLICATION TECHNIQUE

A. Objectives.

Four objectives were tried in experiments to determine the most efficient method.

1. To determine the efficiency of oils on D. brevicomis broods when applied to bark crevices only.
2. To determine effectiveness of oils on D. brevicomis and sugar pine, D. monticolae by increasing bark depressions. (In experiments carried out in 1938 on D. brevicomis by hacking the bark with an axe, no appreciable increase in mortality was noted.)
3. To determine the efficiency of oils on D. monticolae in sugar pine by shaving down the outer bark surface before applying oils.

B. Procedure.

1. Oil 21046/B was used in all tests and applied at a rate sufficient to thoroughly wet the bark surfaces to be treated.
2. Logs of convenient size to roll and measured areas of infested boles were used in the tests with D. brevicomis broods. All tests on D. monticolae broods in sugar pine were carried out on measured sections of infested trees which had been felled and on given areas of bark removed from infested boles.
3. Bark depressions were made in two ways:
   a. By use of a specially constructed tool made to order by the Forest Service. This consisted of an iron plate 4 inches square with iron spikes 3.4 inch long, spaced 3.4 inch apart, welded to the face of it. The plate was welded to one end of a 3# sledge hammer.
   b. By use of an axe. Depressions spaced 2 to 4 inches apart were made parallel with the longitudinal axis of the tree
4. The outer bark surface of infested sugar pines was removed with an axe, and as a rule the remaining bark was 1/2 to 3/4 inch thick.

C. Results:

1. Tables 6 and 7 present the results of the best methods of treatment included in these experiments.
2. Application of oil to bark crevices only caused higher mortality of D. brevicomis broods than a regular spray of the entire bark surface using the same amount of oil.
3. Highest mortality of D. brevicomis broods resulted from hacking the bark with an axe before applying the oil.
4. The specially constructed tool for increasing bark depressions resulted in failure because of clogging. Results obtained from depressions made were not as effective as hacking with an axe.
5. Variations in mortality results in different trees were prevalent, regardless of the method used but, in general, the highest mortality was found in thinner bark.
6. Control of D. monticolae broods in sugar pine by peeling off the brood bark and spraying the inner bark surface resulted in 100 percent mortality in all cases.
7. High mortality of D. monticolae broods resulted when the bark was peeled and left in the shade without further treatment.
8. Effective results were obtained by shaving off the thick outer bark of infested sugar pine logs before applying the oil. (While not compared with the regular application to the bark without first shaving it, past experience has shown the oil to be ineffective to thick bark without further treatment.)
9. Wide variations in mortality of brood were manifested in sugar pine bark shaved down and oiled, even though it was shaved to an approximately equal thickness.
10. Bark hacked with an axe after shaving down, then oiled, resulted in comparatively little more kill than without hacking.

## FINAL FALL OIL CONTROL EXPERIMENT

**Object.**

To compare the efficiency of three new oil formulae with formula 21046/R on D. brevicomis considering their use as practical control oils. This experiment was the last of the seasonal series. Special consideration of brood stages, bark thickness, and other factors was taken in order to get as close a comparison as possible on the different trees used.

**Equipment and Materials.**

1. This project was carried out on four ponderosa pine trees infested with western pine beetle. The trees used contained broods of the third generation for 1934. Trees 1, 2 and 4 were infested in the tops with Ips broods, and tests for oil control were also made on them.
2. The oil formulae used in addition to 21046/R were:
   a. Light stove oil 50%, heavy stove oil 50% naphthaline, ½# per gal.
   b. " " " 75% " " " 25% " " " "
   c. " " " 25% " " " 75% + FDB 180 gms. per gallon

**Procedure.**

1. Four trees from an infested group in the Cascadel basin of the Sierra National Forest were chosen for this work. The trees were quite close together and the brood stages were as near the same in all as it seemed possible to find.
2. The selected trees were felled in a position, in all cases, where the trunk was raised off the ground, either by having fallen over other logs, hummocks or being suspended by the limbs. The felled trees were limbed, measurements taken, and the oil then sprayed onto the trunks, in an amount sufficient to thoroughly wet all bark surfaces, with special emphasis in wetting bark crevices. When the spraying had been completed, the treated trunks were covered with brush in order to keep them shaded.

**Results.**

1. Mortality data obtained in this experiment are presented graphically in figure 12 of the appendix.
2. Highest mortality occurred in tree #4, which was sprayed with a solution of paradichlorobenzine in a mixture of light and heavy stove oils.
3. Comparable results were obtained in tree #3, sprayed with Standard Oil formula 21046/R.
4. Mixtures of light and heavy stove oils in different proportions, with naphthaline dissolved in them, resulted in poor brood control on trees 1 and 3.
5. Inconsistencies and variations in kill were evident on all trees, regardless of exposure or bark thickness. Most uniform and effective results were obtained on the tops of logs and where the bark was thin.

6. An average of 95% mortality of Ips brood followed in 9 square feet of sampled bark treated by an equal mixture of light and heavy stove distillates, in which naphthalene was dissolved. An average of 97% mortality of Ips broods resulted from treatment of 6 square feet of bark treated by oil 21046/R.
7. Further mortality checks will be necessary on all four trees before definite conclusions can be made.

## SUMMARY AND CONCLUSIONS

The results of experiments concluded herein have brought out the following points of greatest importance regarding the oil control method:

1. That temperature limits the time at which mortality takes place. Lower temperatures retard the effectiveness of oils and often decrease their final efficiency, while higher temperatures hasten their efficiency.

2. That oils 23935/R, 23930/R, stainless creosote, 23906/R, 23905/R 23903/R, and 23904/R, stated in order of efficiency, are the best oils found for control of bark beetles to date. Of these, oil 23935/R is considered most effective. Combinations of oils and chemicals mixed in the field gave most efficient control by use of light and heavy stove oils in which was dissolved either paradichlorobenzine or naphthalene in measured quantities. The PDB combination appeared most promising in preliminary tests, but neither PDB nor naphthalene in the base oils used was quite as effective as the best of the Standard Oil formulae.

3. That great variations in bark thickness, density, and oil penetration exist at different heights of the same tree, and in different trees. While density and penetration tests were carried on principally with ponderosa pine, indications were evident in a few tests carried out on sugar pine that an even greater variation exists in this species. These conditions make uniformity of results in oil treatment impossible regardless of what formula is used, unless they can be controlled.

   If the physical bark factors governing oil penetration cannot be isolated and controlled, the oil control method must be abandoned, except for thin barked trees like lodgepole of the Ips infested tops of ponderosa and sugar pines.

4. That greater efficiency of oils is attained on infested logs by oiling all bark surfaces, with special attention to wetting the bark crevices. An increase in bark depressions made by an axe before oil application is an advantage to oil penetration and effectiveness, especially in ponderosa pine, but is of little advantage in sugar pine.

Mature infested sugar pines cannot be treated effectively by oils unless the bark is removed and the inner surface sprayed, or unless the outer bark surface is cut down to a thickness of 1/2 inch. The method employed is limited by the tightness of the bark to the bole. Loose bark, peeled off and oiled, or peeled off and left untreated will result in heavy mortality of broods, but as a rule oiling is much safer if the broods are in a well advanced stage. Tight bark, found on trees killed during the summer, shaved down to a thickness of 1/2 inch, and then sprayed with oils will result in considerable kill, but variations occur in different trees, often to the extent of being inefficient.

Control of broods on the bottoms of logs by use of oils is a problem, regardless of whether the logs are raised above the ground surface sufficient/to wet thoroughly. This is because gravity causes the oil to drip rapidly from the bark. Greatest mortality occurs on the tops and sides of treated logs, and least on the bottom, even though all surfaces are wetted equally.

5. Resistance of D. brevicomis and D. monticolae to oils is evident. Individuals of both species, in larval, pupal, and adult stages, found alive in oil saturated bark indicates that variations in mortality results are in part due to this cause. Considerable experimentation can still be carried out along this line, using naked brood of each species.

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Relation Between Temperature and Effectiveness of Pine Bark Oil Formulae21046/R on Dendroctonus brevicomis broods. Berkeley, California, March 20, 1934

Summary of Results---Dinkey Oil Control Project, 1933. Berkeley, Calif., Oct. 8, 1934.

Final Mortality Results of Oil Treated Ponderosa Pine infested by D. brevicomis and M. gentilis. Berkeley, Calif. Oct. 10, 1934.

APPENDIX

Table 1

WINTER OIL TESTS ON MELANOPHILA GENTILIS

LARVAE IN PONDEROSA PINE

Mortality after 35 days' Exposure
April 25 - May 30, 1934.

| Log Number | Oil Formula | Living: Brood | Dead: Brood | Mortality |
|---|---|---|---|---|
| 1 | 23905/R | 16 | 40 | 71.4 |
| 2 | 23908/R | 7 | 28 | 80. |
| Check | None | 36 | 8 | 19 |

Bark area of all logs was 6 square feet

Bark thickness was one-half inch

Oil applied at rate of .031 gals. per sq. ft.

Table 2

Effect of formulae developed in the field on Dendroctonus brevicomis broods at summer temperatures. Period of exposure- 7 days. Oil applied at rate of .025 gals. per sq. ft.

| Formula: | % Mortality |
|---|---|
| Wood tar distillate | 10 |
| " " " 50%, combined with light stove oil (heavy friction) 50% | 12 |
| " " " 50% " " light stove oil (light friction) 50% | 55 |
| Coal tar 33-1/3%, mixed with light stove oil 66-2/3% | 35 |
| Light stove oil 50%, mixed with crankcase drainings 50% | 36.5 |
| " " " 75% " " " " 25% | 40. |
| Coal tar | 50. |
| Light stove oil 90%, crankcase drainings 10% | 54 |
| Heavy " " 50% light stove oil 50% | 54.2 |
| " " " 50% " " " 50%+ PDB 45 gms. per qt. | 56 |
| Crankcase drainings 25%, heavy stove oil 75% | 57 |
| Coal tar 50%, light stove oil 50% | 61.5 |
| Heavy stove oil 80%, kerosene 20% | 63 |
| " " " 50%, crankcase drainings 50% | 64 |
| Light " " | 67.3 |
| Heavy stove oil 80%, light stove oil 20%- PDB 10 gms. per qt. | 71. |
| " " " | 73 |
| Light " " and PDB 90 gms. per qt. | 73.3 |

Table 2 (Cont'd)

| Formula | % Mortality |
|---|---|
| Automobile crankcase drainings | 74. |
| Light stove oil 50%, heavy stove oil 50% & naphthalene 1/2 lb. per gallon | 82.2 |
| Heavy " " and beta-naphthol 20 gms. per qt. | 83 |
| Light " " 25%, heavy stove oil 75%, & PDB 45 gms. per qt. | 86 |
| " " " 75%, " " " 25%, " naphthalene 1/2 lb. per gallon | 86 |
| Heavy " " 50%, kerosene 50% | 86 |
| Crankcase drainings 60%, heavy stove oil 30%, kerosene 10% | 90 |
| Heavy stove oil and PDB 45 gms. per gallon | 92.1 |

Table 3

Relation between Longitudinal Penetration of oils in bark and Mortality of D. b. broods

| Tree # | Log | Penetration in cm. per second | % Mortality | Remarks |
|---|---|---|---|---|
| 7 | 1 | .0009 | 85 | |
| | 2 | .0012 | 64 | |
| | 3 | .0011 | 70 | |
| | 4 | .0008 | 79 | No correlation |
| 9 | 1 | .0014 | 59 | |
| | 2 | .0012 | 66 | |
| | 3 | .0013 | 69 | |
| | 4 | .0009 | 75 | |
| | 5 | .0009 | 97 | No correlation |
| 10 | 1 | .0010 | 91 | |
| | 2 | .0010 | 93 | |
| | 3 | .0010 | 95 | No correlation |

Table 4

Relation Between Vertical Penetration of Oils in Bark and Mortality of D. b. brood

| | | | | |
|---|---|---|---|---|
| 2 | 2 | .0037 | 64 | |
| | 3 | .0045 | 70 | |
| | 4 | .0047 | 79 | Correlation |
| 12 | 1 | .0029 | 68 | |
| | 2 | .0046 | 63 | |
| | 3 | .0030 | 90 | |
| | 4 | .0067 | 89 | No correlation |
| 10 | 2 | .0093 | 98 | |
| | 3 | .0083 | 95 | Correlation |
| 17 | 1 | .015 | 90 | |
| | 2 | .016 | 86 | No correlation |

Table 5

Relation Between Brood Mortality and Density of Bark when Treated by Oil 23036/R. Bark 3/4 inch thick. Oil Application- .025 gals. per sq.ft.

| | | | | |
|---|---|---|---|---|
| 1 | 1 | .370 | 85 | |
| 2 | 1 | .356 | 74 | |
| 3 | 1 | .345 | 69 | |
| 4 | 2 | .464 | 87 | |
| 6 | 3 | .383 | 84 | |
| 7 | 3 | .356 | 85 | |
| 9 | 3 | .398 | 69 | |
| 10 | 1 | .334 | 91 | |
| 11 | 3 | .418 | 67 | |
| 12 | 3 | .396 | 90 | |
| 13 | 2 | .430 | 85 | |

Table 5 (Cont'd)

| Tree # | Log | Penetration etc. | % Mortality | Remarks |
|---|---|---|---|---|
| | Oil #1046/R. Bark 1/8 inch thick. | | | |
| 7 | 4 | .387 | 79 | |
| 8 | 2 | .481 | 98 | |
| 9 | 4 | .474 | 75 | |
| 10 | 2 | .440 | 98 | |
| 11 | 4 | .522 | 98 | |
| 12 | 4 | .494 | 89 | |
| 13 | 3 | .505 | 85 | |

Table 6

Comparative Effectiveness of Different Methods in Technic of Oil Application on Dendroctonus brevicomis Brood Mortality. Mortality from samples 1 sq.ft in area.

| Tree #: | Thickness of bark | Surface Spray | Crevice Spray | Bark Nicked and sprayed |
|---|---|---|---|---|
| 16 | 1¼ in. | 86 | 88 | 74 |
| | ⅜ " | 98 | 100 | 100 |
| 17 | 1 " | 87 | 89 | 95.4 |
| | ½ " | 89.2 | 97 | 93 |
| 19 | 1¼ " | 64 | 71 | 77 |
| | ¾ " | 100 | 97 | 100 |

Table 7
in % Mortality

Comparative effectiveness of oil #1046/R in Relation to different methods of treatment of Dendroctonus monticolae infested sugar pine bark. Dosages applied at rate of .025 gals. per sq. ft.

| Tree No. | Area of Treated Sample Sq. ft. | Method of Treatment: Peeled & sun-cured | Peeled & left in shade | Peeled & oiled inner surface | Shaved down and oiled | Shaved down hacked & oiled | Untreated checks |
|---|---|---|---|---|---|---|---|
| 1 | 85 | 100 | | 100 | | | 8.2 |
| 2 | 15 | 100 | 99 | 100 | | | |
| 3 | 40 | | 100 | 100 | 57.4 | | 3.9 |
| 4 | 80 | | 80 | 100 | 97.7 | | 8.3 |
| 5 | 310 | | | 100 | 76 | | |
| 6 | 70 | | | | 89.7 | 96.9 | 1.4 |
| 7 | 60 | | | | 67.5 | 77.0 | 23.0 |
| 8 | 120 | | | | 96.8 | 98. | 3.0 |

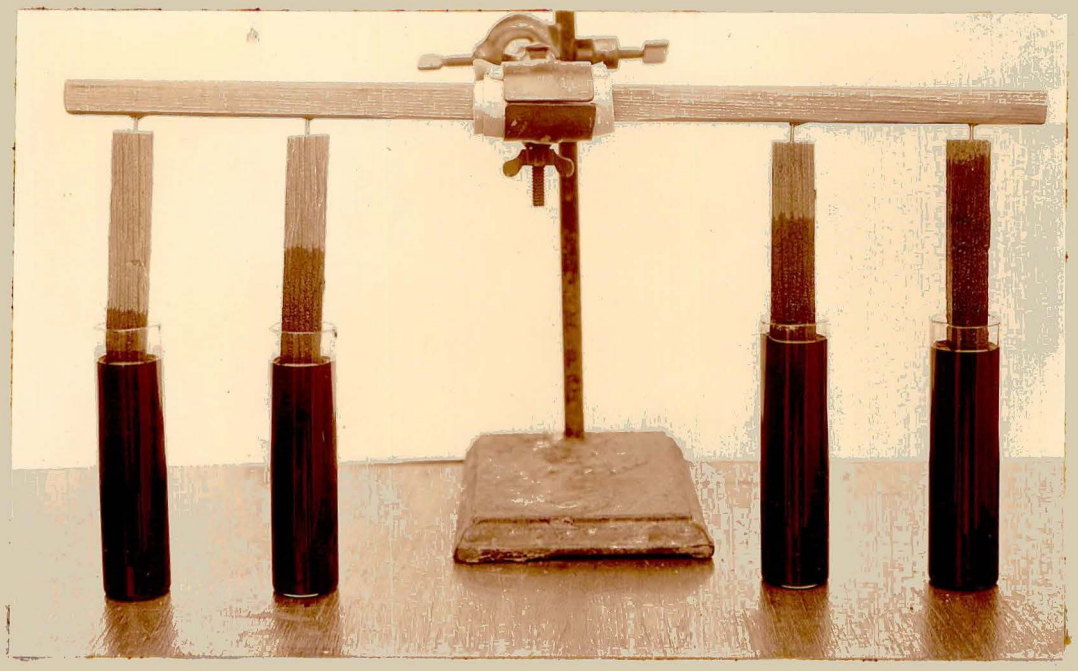


Photo 1 (8699a) Set up for determining rate of longitudinal penetration of oils in bark of ponderosa pine. The test at the extreme right is nearly completed. The one at the extreme left is just starting.- Photo by J.E.Patterson.

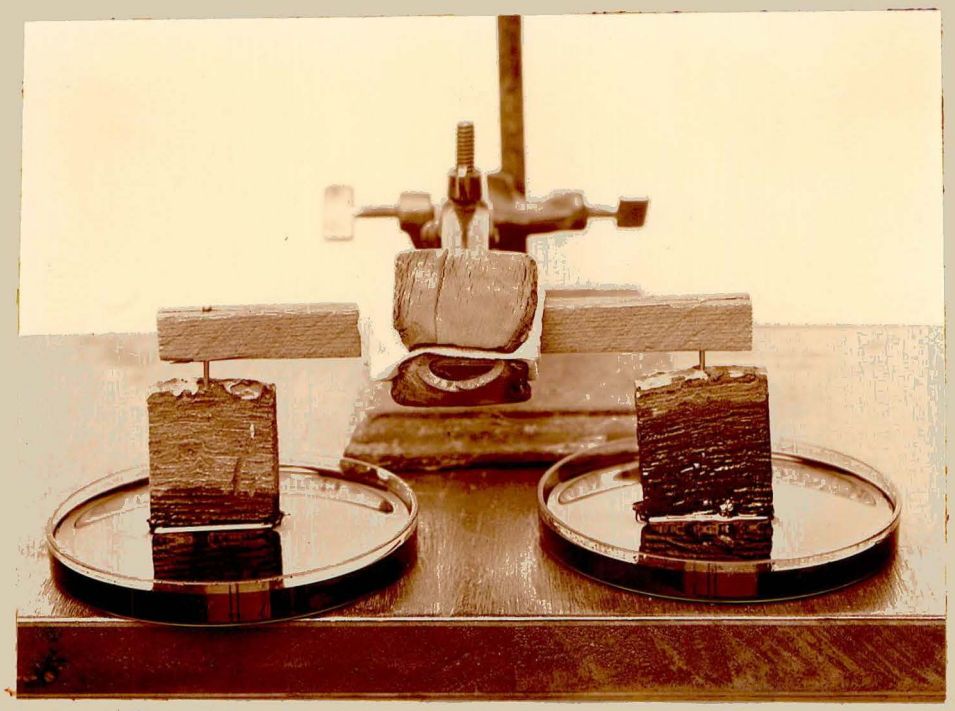
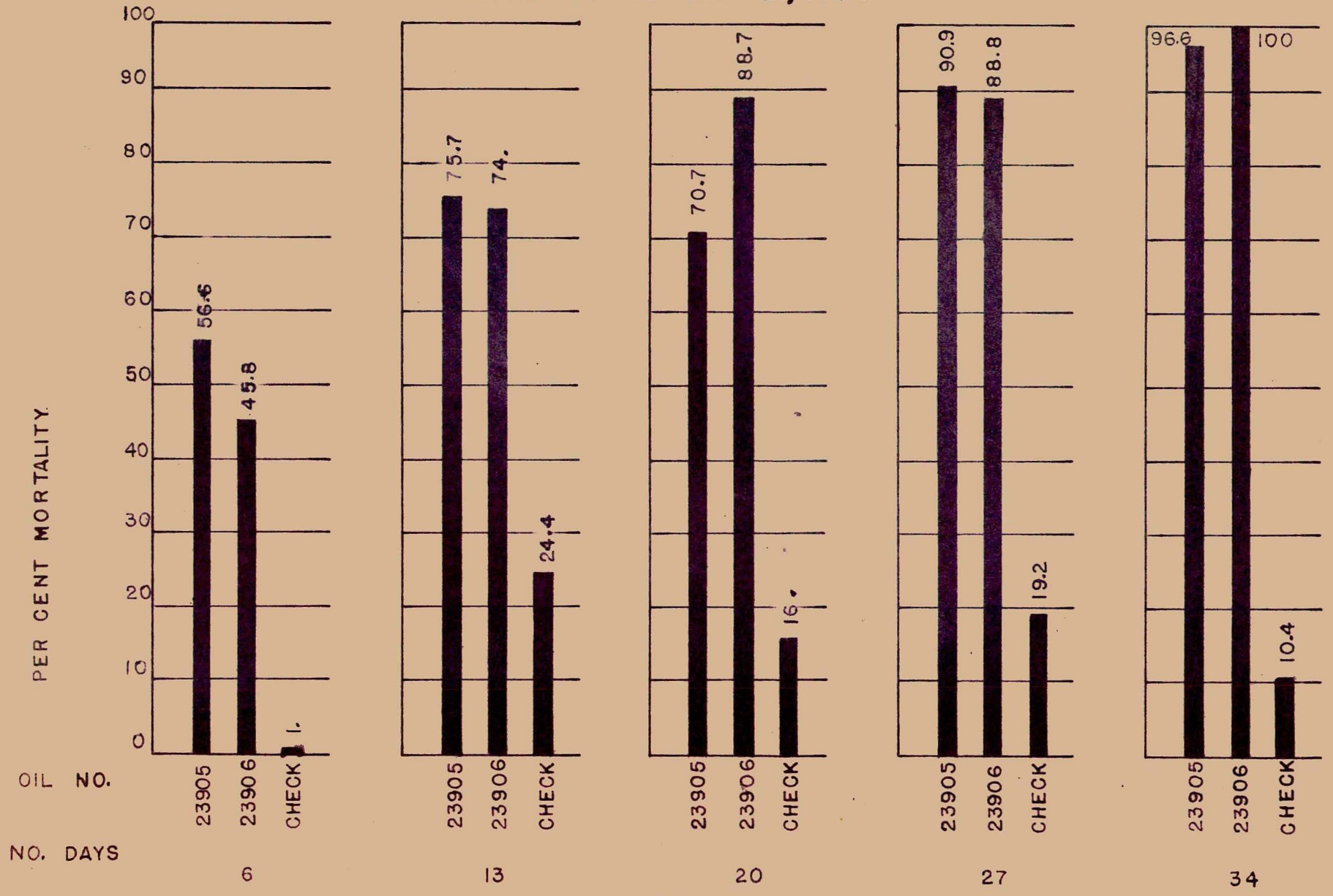


Photo 2 (8699b) Set up for determining rate of vertical penetration of oils in bark of ponderosa pine. The test at the right is nearly completed. The one at the left is just starting.- Photo by J. E. Patterson

FIGURE I. COMPARATIVE MORTALITY OF WINTER OILS ON WESTERN PINE BEETLE IN PONDEROSA PINE AT DIFFERENT PERIODS OF EXPOSURE. APRIL 17 TO MAY 21, 1934




BARK THICKNESS WAS ONE INCH THROUGHOUT EXPERIMENT.

ALL OILS APPLIED AT RATE OF .025 GAL. PER SQUARE FOOT.

1. SQUARE FOOT SAMPLES CHECKED FOR ALL COUNTS.

FIGURE 2. COMPARATIVE MORTALITY OF D.B. BROODS SUBJECTED TO DIFFERENT OILS AT WINTER TEMPERATURES.

MAY 30 TO JUNE 18.

(OIL APPLIED = .025 GALS. PER SQ. FT.)

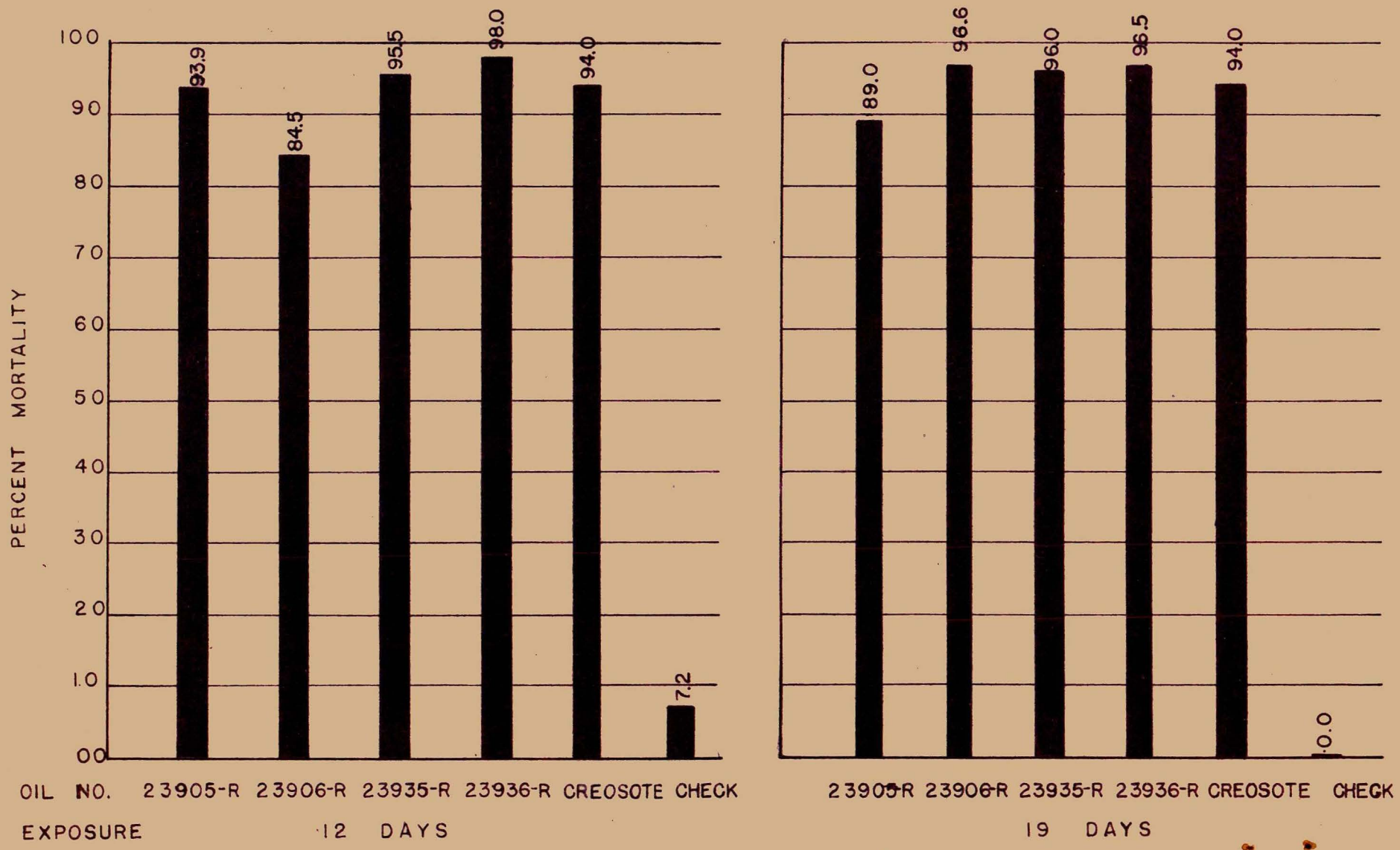
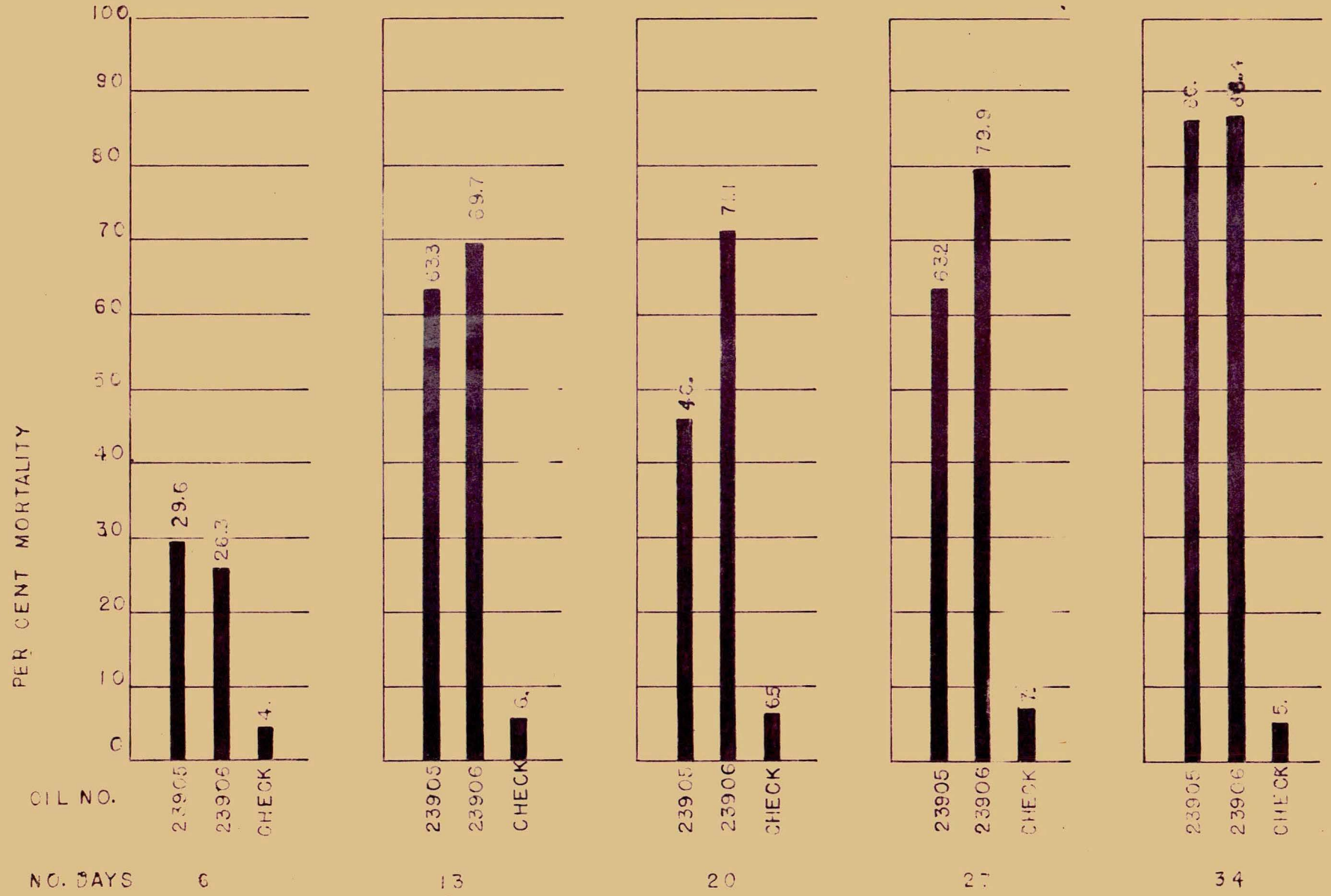


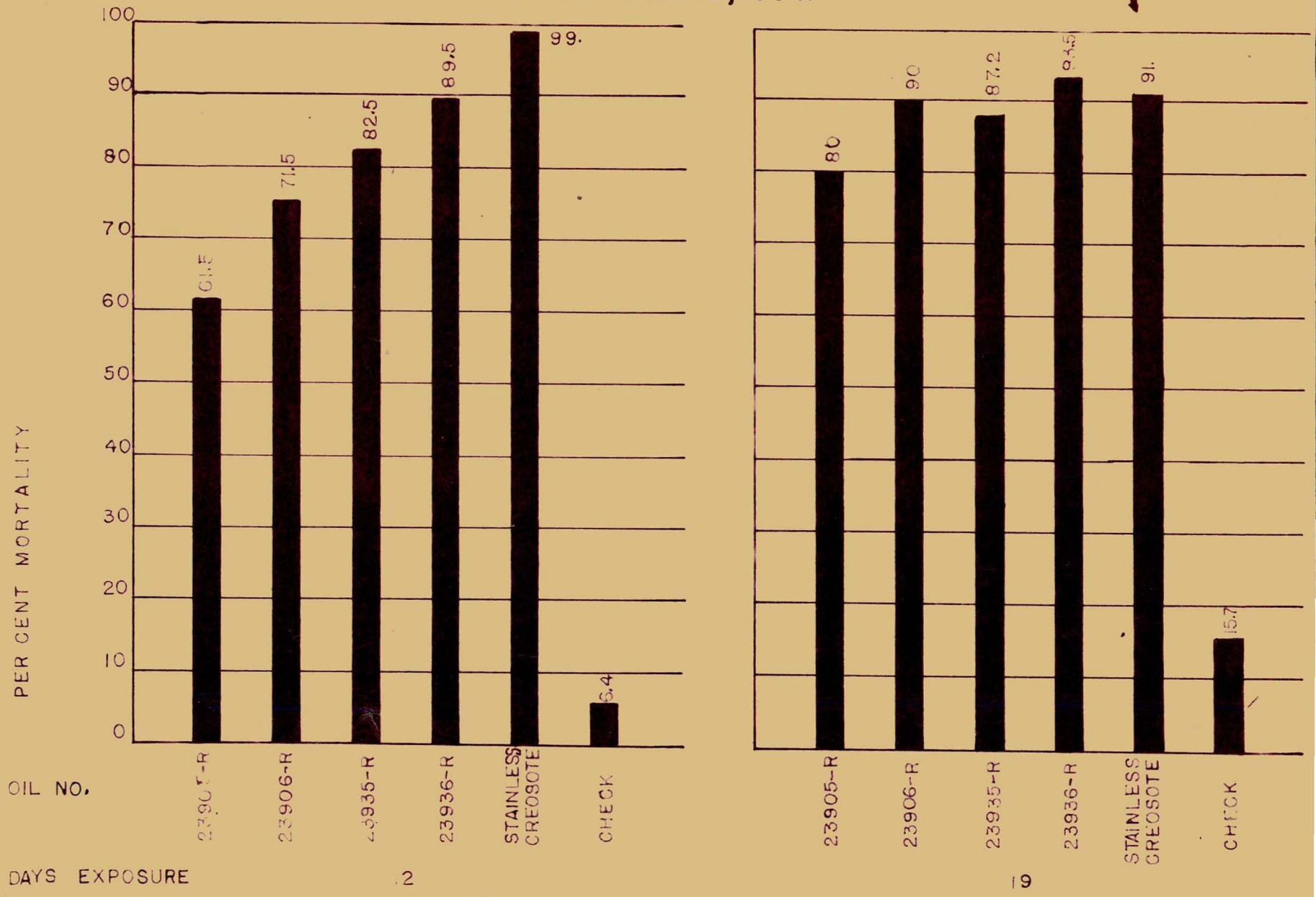
FIGURE 3. COMPARATIVE MORTALITY OF WINTER OILS ON MOUNTAIN PINE BEETLE IN SUGAR PINE AT DIFFERENT PERIODS OF EXPOSURE. APRIL 17 TO MAY 21, 1934.




BARK THICKNESS VARIED FROM ONE-HALF TO THREE-QUARTERS INCH.

ALL OILS APPLIED AT RATE OF .025 GALS. PER SQ. FT.

FIGURE 4. COMPARATIVE MORTALITY OF D.M. BROODS IN LODGEPOLE PINE SUBJECTED TO DIFFERENT OILS AT WINTER TEMPERATURE. MAY 30 TO JUNE 18, 1934.




OIL APPLIED AT RATE OF .025 GAL. PER SQUARE FOOT.

FIGURE 5. DAILY MAXIMUM AND MINIMUM AIR TEMPERATURES AT WINTER OIL STATION. ELEVATION 7200 FEET.

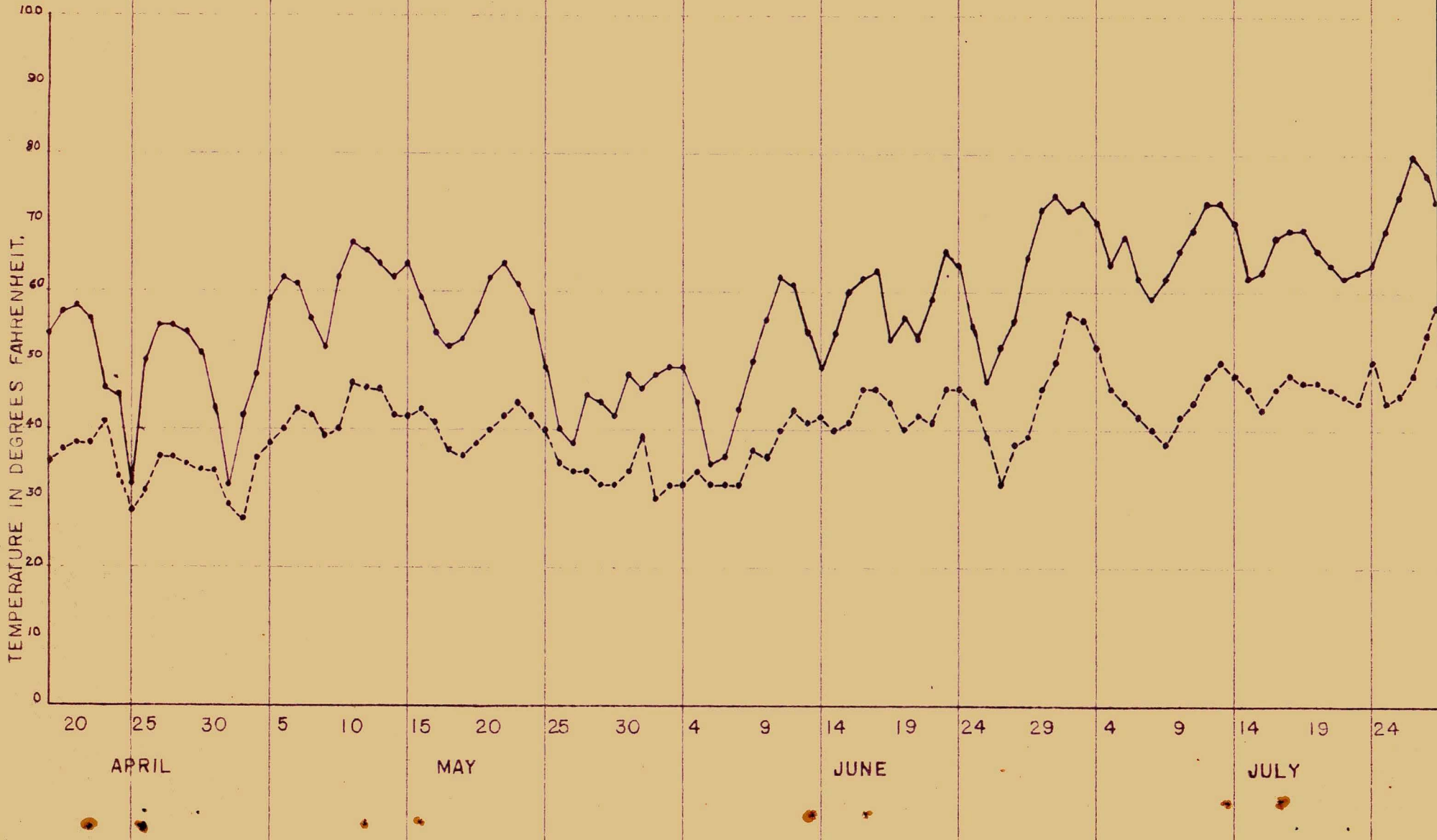


FIGURE 6. COMPARATIVE TOXICITY OF OIL FORMULAE ON D.B. BROODS ON TOP, SIDE AND BOTTOM OF LOGS EXPOSED FOR DIFFERENT PERIODS AT SUMMER TEMPERATURES.

OILS APPLIED AT RATE OF .025 GALLON PER SQ. FT.

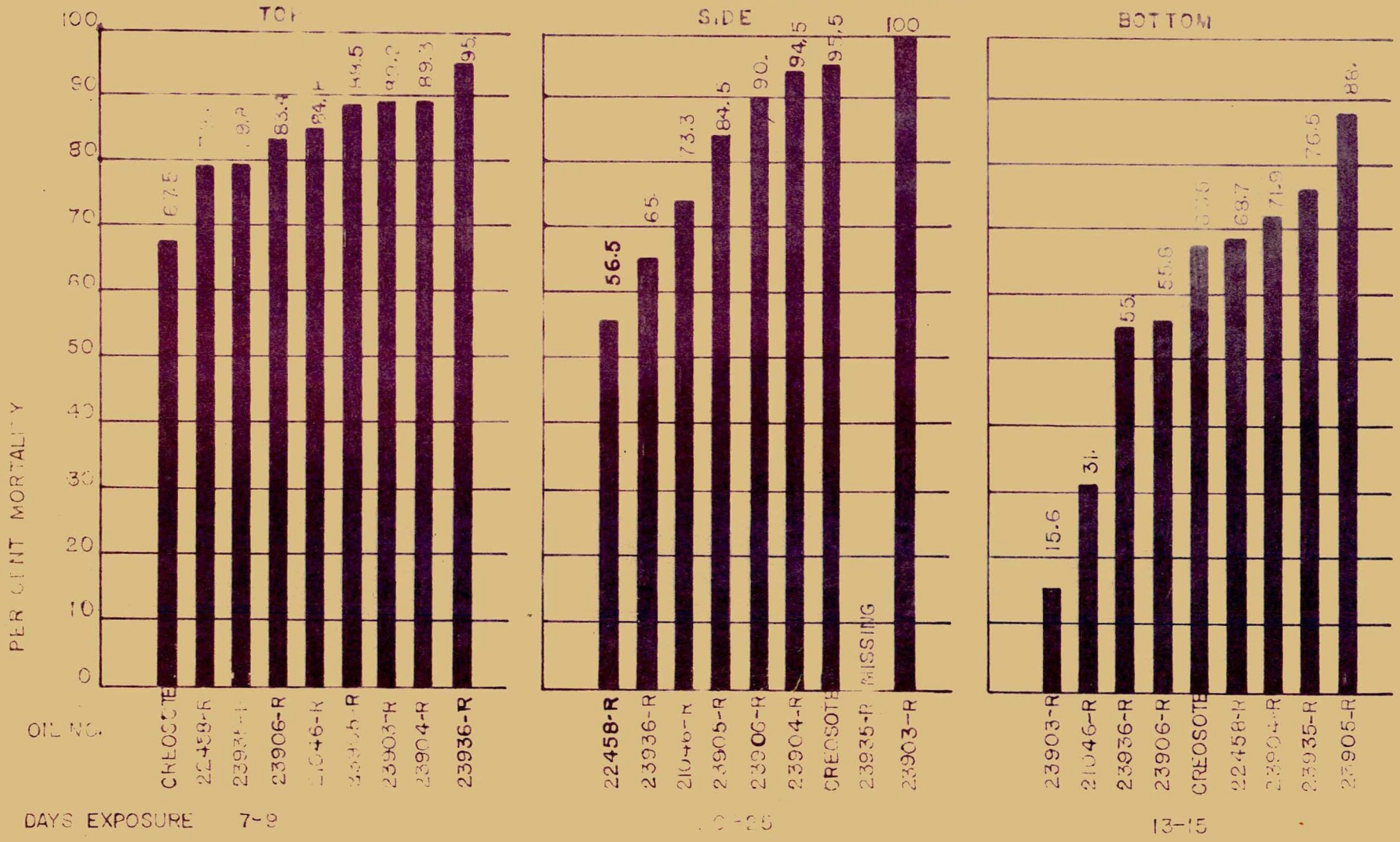


FIGURE 7. COMPARATIVE EFFECT OF DIFFERENT OILS ON D.M. BROODS FROM SUGAR PINE AFTER 19 DAYS EXPOSURE AT SUMMER TEMPERATURES.

OIL APPLIED= .050 GAL. PER SQ. FT.

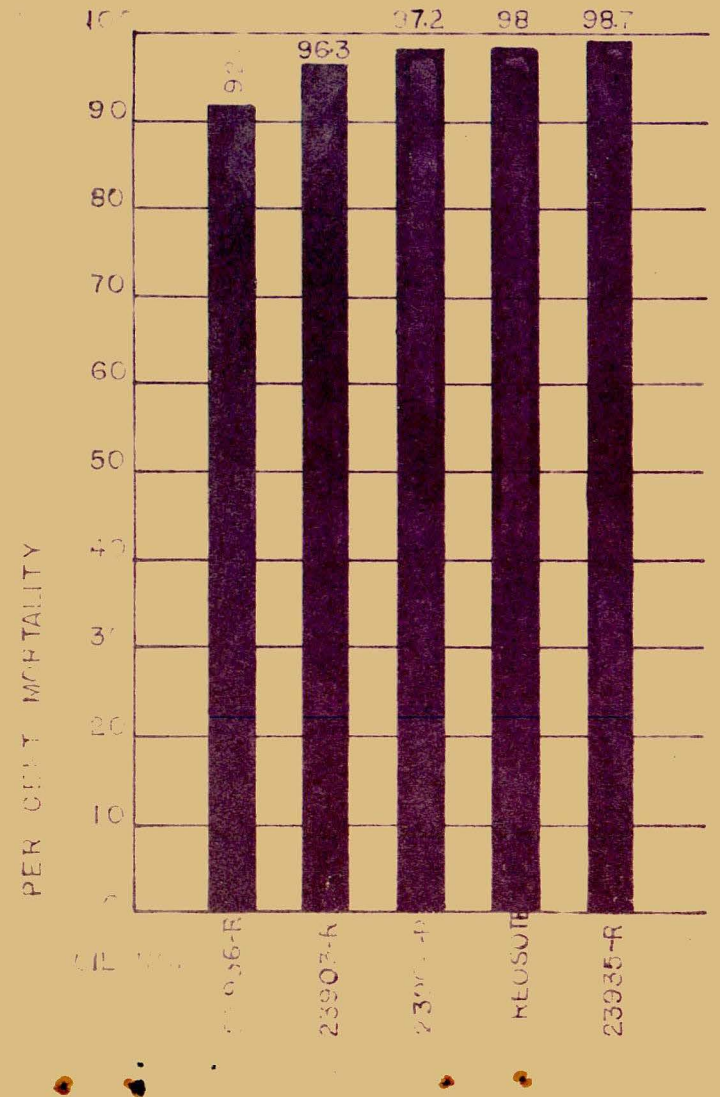



FIGURE 8. COMPARATIVE EFFECT OF DIFFERENT OILS ON LODGEPOLE D.M. BROODS AFTER 15 DAYS EXPOSURE AT SUMMER TEMPERATURES. MAY 31 TO JUNE 21 1934.

OIL APPLIED= .025 GAL. PER SQ. FT.

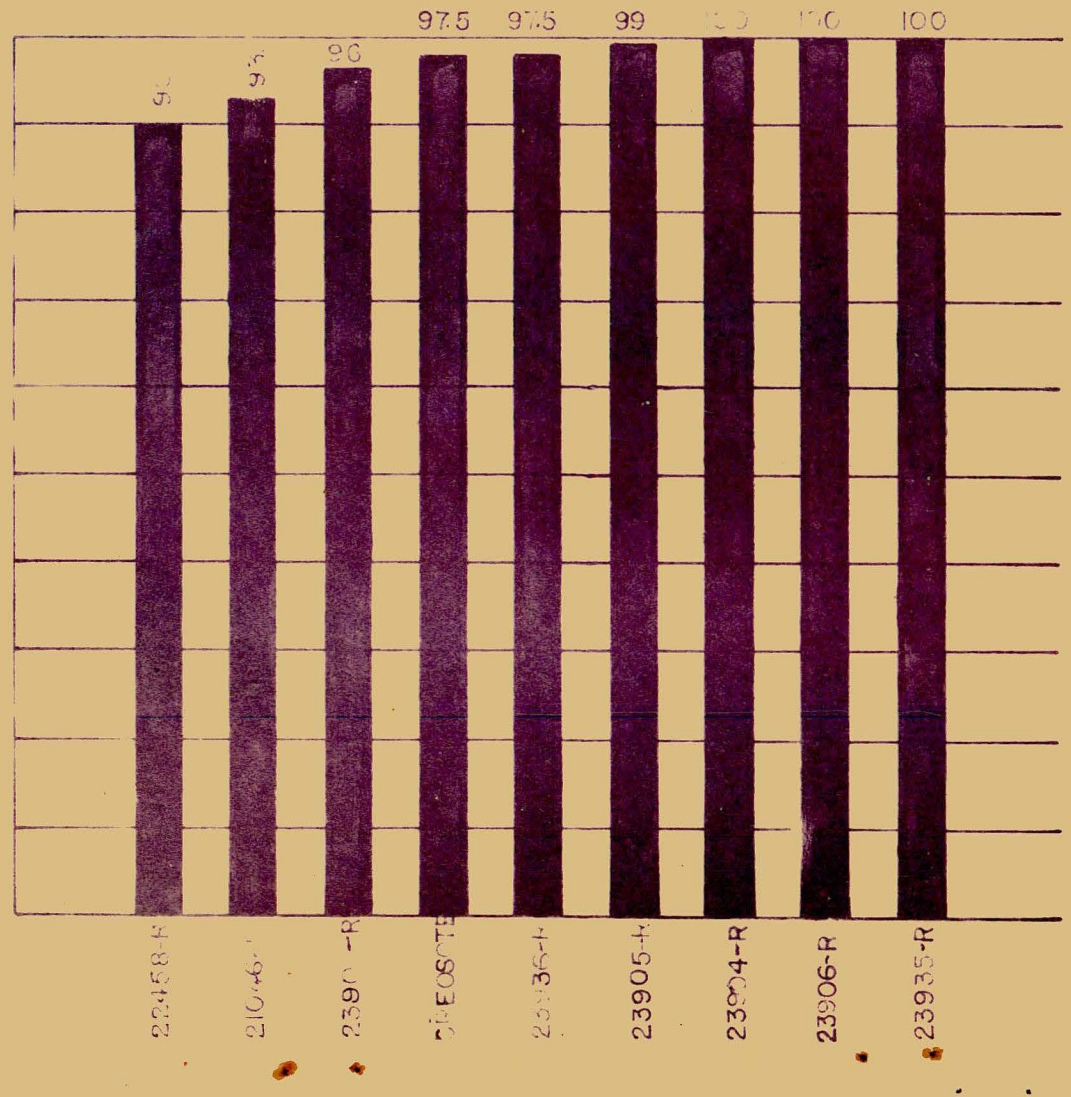


FIGURE 9. COMPARATIVE EFFECT OF DIFFERENT OILS ON MELANOPHILA LARVAE IN PONDEROSA PINE AT SUMMER TEMPERATURE.

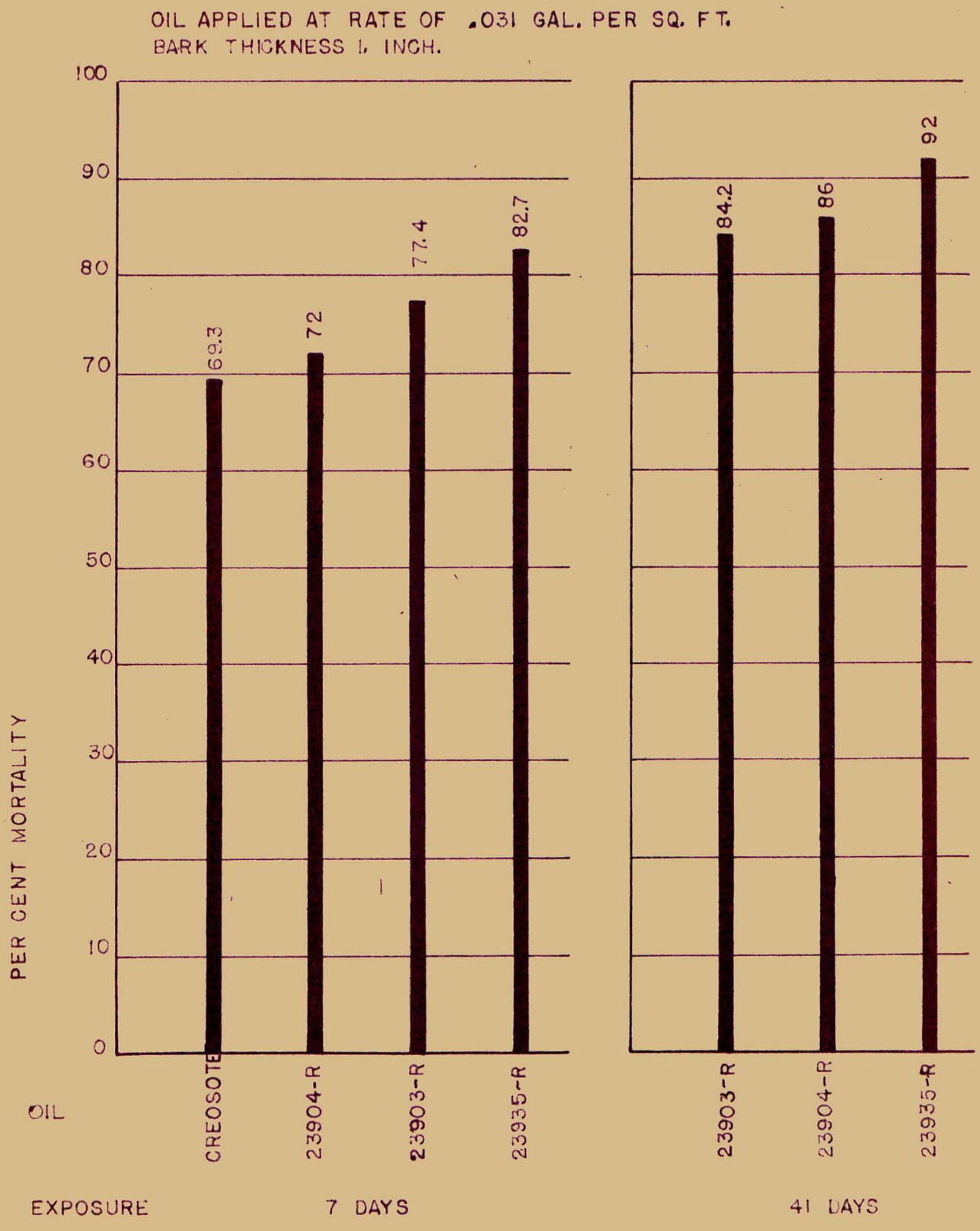


FIGURE 10. DAILY MAXIMUM AND MINIMUM AIR TEMPERATURES AT SUMMER OIL STATION, 3000 FEET ELEVATION.-

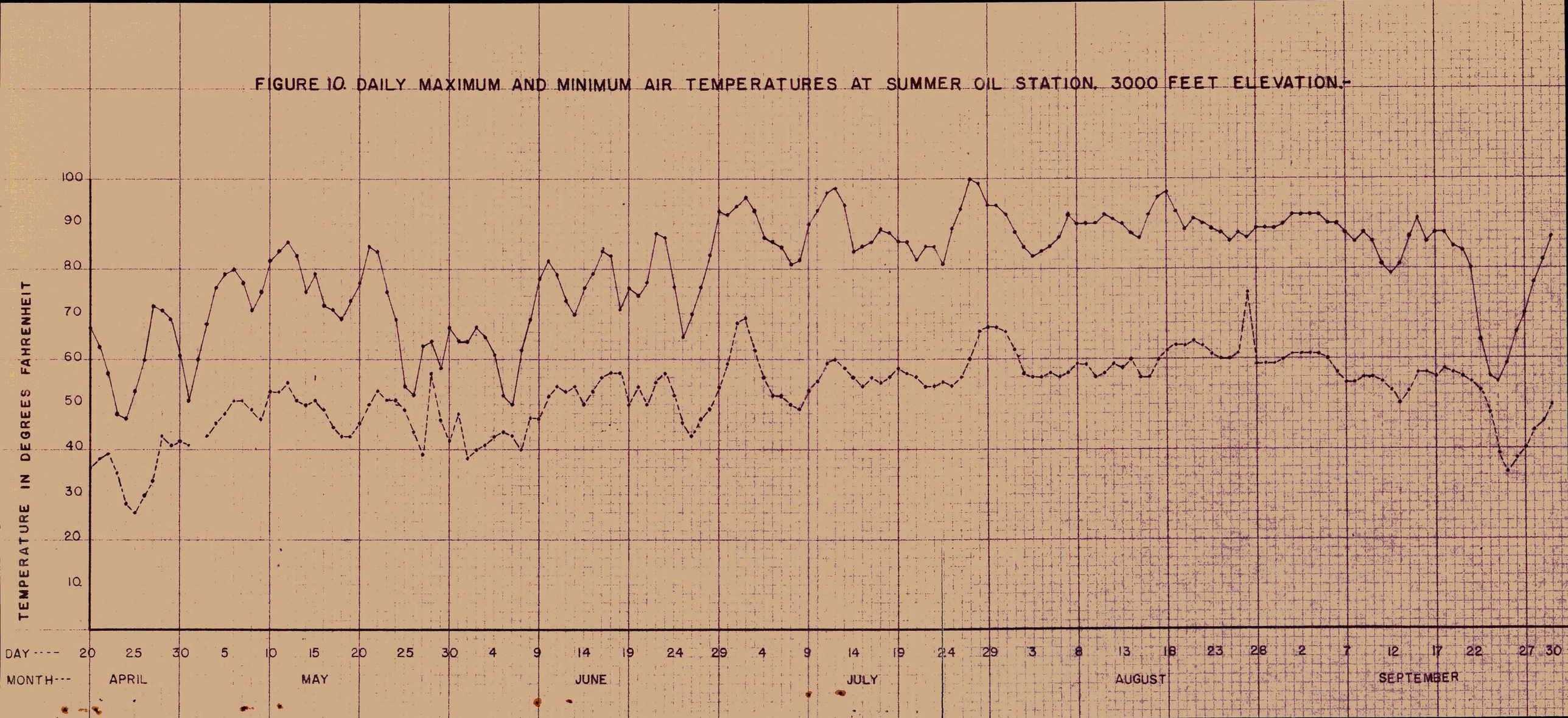


FIGURE 11. RELATION BETWEEN BARK THICKNESS AND EFFECTIVENESS OF OIL 21046-R ON FOUR REPRESENTATIVE TREES.

OIL APPLIED AT RATE OF .025 GAL. PER SQ. FT.

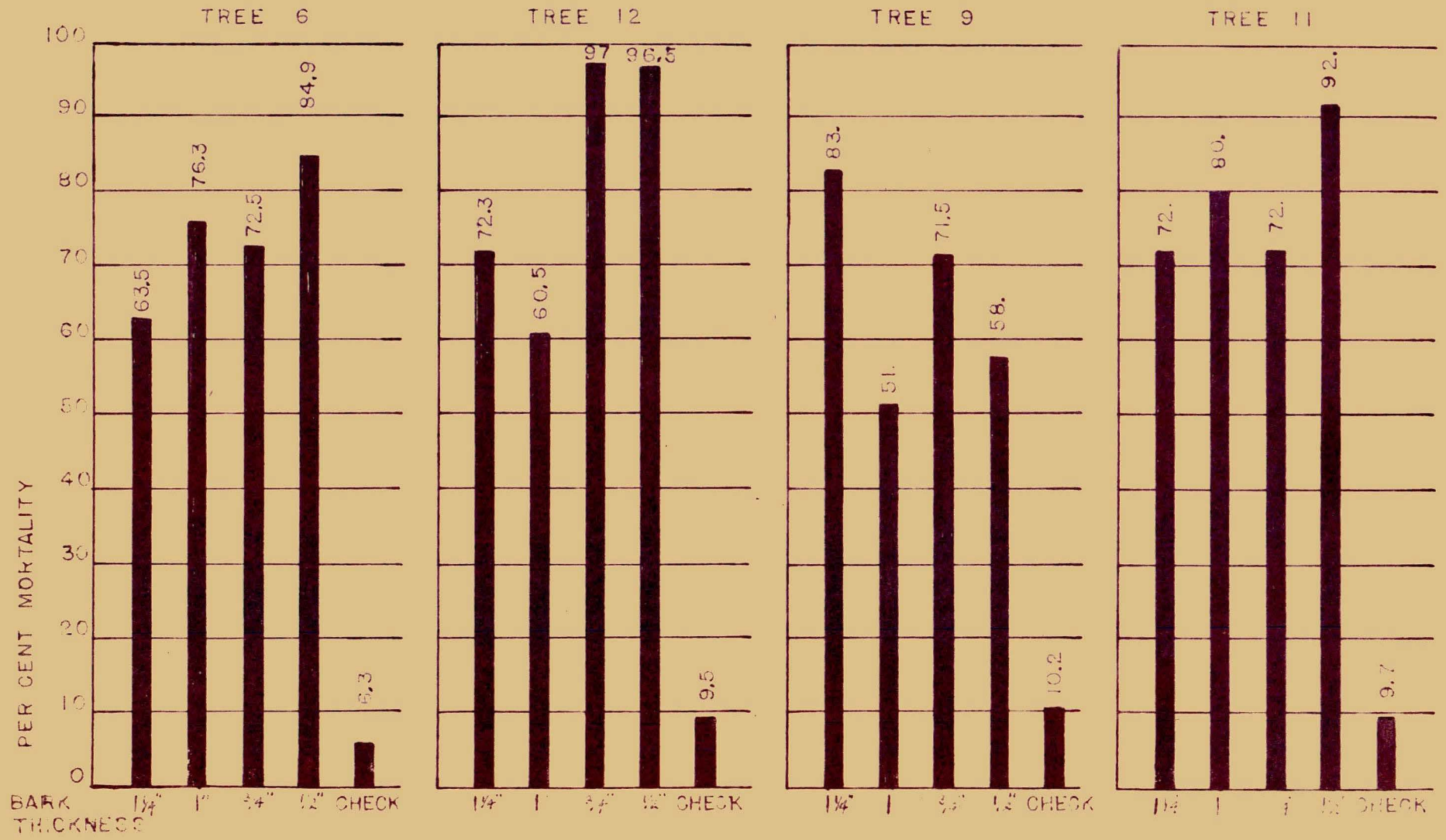


FIGURE 12. COMPARATIVE EFFECTIVENESS BETWEEN OIL 21046-R AND NEW FORMULA APPLIED IN EQUAL AMOUNTS ON FOUR D.B. INFESTED PONDEROSA PINES.

MORTALITY DATA FROM TOP, SIDE, AND BOTTOM AT ¼" INTERVALS IN BARK THICKNESS